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Nutrition of small ruminants on grazing lands in dry zones of India

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Abstract
Grazing lands in the dry zones of the country are the main source of fodder for small ruminants. It is declining rapidly with urbanization; on the other hand, livestock population is increasing. This is resulting in overgrazing and deterioration of productivity of lands from poor to very poor conditions. Still, it is a major source of fodder for more than 90% of small ruminants in the country. The rehabilitation of existing grazing lands with improved pasture grasses is one of the options to increase the productivity of these lands and small ruminant production and livelihood security in an eco-friendly manner. The study indicated that rehabilitation of community lands with cenchrus pasture increased the yield by 5-7 times and further establishment of silvipasture on waste lands in dry zones ensured quality vegetation to animals in addition to higher production and also in scarcity period. The grazing of sheep and goats on grassland and silvipasture improved the growth, production and reproduction and higher return to farmers at relatively low cost of production. In dry land zones, scarcity of fodder during summer is a serious issue and supplementary feeding of concentrate, conserved fodder and tree leaves to animals revert the negative effect of feed scarcity and improved the animal production. In this review, attempts were made to review the earlier studies on nutrition of small ruminants on existing grazing lands and grass pastures to develop future strategies for pasture development and supplementary schedules for animals during scarcity period.

Keywords: Dry zones, Grazing lands, Grazing systems, Nutrition, Small ruminants

Introduction
Small ruminants (sheep and goats) play an important role in source of income and livelihood of people in arid and semi-arid dry regions of the country. There are 74.26 million sheep and 148.88 million goats in the country (Livestock Census, 2019). Out of it, about 90 % of small ruminants are maintained exclusively under extensive range management on pastures, native ranges, fallow land, wasteland and forest for their feed and fodder requirements. As per estimates, the country's pastures have reduced from about 70 million ha in 1947 to just about 38 million ha in 1997 (Anonymous, 2011). India lost 31 per cent or 5.65 million hectares of grassland area in a decade from 2005 to 2015 as per data presented by the Union government in the United Nations Convention to Combat Desertification (UNCCD, 2019) during the 14th Conference of Parties (COP) at New Delhi. The total grassland areas reduced from18 million ha to 12.3 million ha between 2005 and 2015. The country has also lost 19 % of its common lands (90.5million ha in 2005 to73.02 million ha in 2015).The major proportion of this loss of pasture lands is reported from the village commons. Small ruminant production on commons is important both in terms of the meat, wool and milk produced and number of people depend on them for their livelihood. These commons in the country supports full spectrum of production from stationary to traditional nomadic system where they supply fodder, fuel and other minor forest products (Singh *et al.,* 2005).

It has been widely accepted that progressive shrinkage of grazing lands, simultaneous increase in livestock population, over grazing and soil erosion and ecological degradation and long dry spell (8-9 months) are main constraints to small ruminant production on grazing land in semi-arid and arid regions (Shinde and Bhatta, 2002). Heavy grazing pressure, poor management and poor rainfall conditions in dry regions are deteriorating the forage yield and carrying capacity (0.68 ACU ha^{-1}) of grazing lands (Yadava *et al.,* 2018).Small ruminants have better efficiency for utilizing poor quality grazing resources and converting them into quality animal protein. Grazing lands are cheapest source of nutrients for small ruminants. Feed represent the highest cost of production in small ruminant farming, so grazing pasture will continue to play an important role in small ruminant production systems. Poor nutrition is responsible for many of the health and production problems in sheep and goat rearing, including poor growth, reproduction, neonatal death, fertility, fecundity, susceptibility to gastrointestinal parasites, mineral deficiency etc. In view of the above situation, nutrition of sheep and goats on range and pasture in dry region, nutrient supply from pastures, selective grazing by animals and effect of supplementation have been reviewed to improve their grazing management and production.

Small ruminants' resources and contribution

Small ruminants provide major source of income and livelihood to millions of farmers in arid, semiarid dry regions of the country. Goat and sheep are known as the poor man's cow or bank on hooves which survive with least resources on grazing lands in dry areas. They are primarily reared on grazing lands which includes pastures, rangelands, barren lands, fellow lands and other waste lands. As per recent livestock census 2019, country has 74.26 million sheep and 148.88 million goats, contribute together to 223.14 million small ruminants (41.57% of livestock population; Table 1). Sheep contribute 677.99 million kg and 40.42 million kg wool and goat contribute 1097.91 million kg meat and 6.09 million tonnes milk. Contribution of sheep and goat to total meat production is around 21.89% (8.11 million tonnes) (Livestock Census, 2019).

Table 1. Sheep and goat population and their productions

Parameters	Sheep	Goat	Total
Population (million)	74.26	148.88	223.14
Meat (million kg)	677.99	1097.91	1775.90
Wool (million kg)	40.42	-	40.42
Pashmina (tonnes)	-	50.00	50.00
Milk goat (million tonnes)	-	6.09	6.09

Grazing resources for small ruminants

Grazing of animals is estimated to occur on about 40% of the land area in the country, most of these lands are not designated as grazing lands. Only 10.90 million ha of land in the country is classified as permanent pastures/ grazing lands (Table 2). As per estimates, the country's grazing lands have reduced from about 70 million ha in 1947 to just about 38 million ha in 1997. The major proportion of this loss of pasture lands is reported from the village common lands. The common property resources (CPRs) is important source of livelihood and income for poor people in all the states. CPRs contribute and allow considerable access to all users.

Table 2. Grazing resources in India.

Resources	Area (million ha)	Perce -ntage
Forests	69.41	22.70
Permanent pastures, grazing lands	10.90	3.60
Cultivable wasteland	13.66	4.50
Fallow land	24.99	8.10
Fallow land other than current fallows	10.19	3.30
Barren uncultivable wastelands	19.26	6.30
Total common property resources other than forests	54.01	17.70

Source: ICAR (2009)

Estimates suggest that nearly 70% of the households in the arid, semi-arid and sub-humid regions of India graze their livestock on Commons and 45% of their fodder requirements are met from commons alone. Further, not only small ruminants, but also stall fed animals– buffaloes and crossbred cattle also depend on the commons for meeting more than 20% of their fodder requirements (FES, 2010).

Indian grazing lands has the capacity for grazing only a 31 million livestock, contrary to it, around 100 million livestock graze in the same lands. The pressure has grown steadily over two per cent per annum for the last two decades. The grazing pressure on common property resources is increasing as a combined result of the reduced area and growing livestock population. Further increased pressure has over exploited and degraded the resources leading to permanent disruption or elimination of vital biophysical processes, and nature's regenerative activities (Roy *et al*., 2019). These disruptions reduce the efficacy of farmers' traditional strategies against environmental stress in dry regions. Moreover over stocking and over grazing on available land successively disappearing the palatable species of grasses, forbs and trees. In semiarid regions of Rajasthan, forage yield of rangelands as 4.92 DM q/ha in monsoon and 1.36 DM q/ha in winter has been reported which can be increased by rehabilitation of lands with *Cenchrus ciliaris* to 27- 33 q DM/ha and with *Cenchrus setigerus* to 28-45 q DM/ha and by introduction of multi component silvipasture of grass, shrubs and trees to 22 q DM/ha (Shinde and Sankhyan, 2017). Further yield and quality of common property resources are deteriorating very rapidly and there is an urgent need to maintain stable grazing resources for sustainable small ruminant production by rehabilitating the community grazing land through establishment of perennial greases and trees and gradually elimination of unproductive animals from population to spare available feed resources for productive animals.

Estimation techniques of nutrient intake and digestibility

In India, research on nutrition of sheep and goats on pasture grazing was started long back in 1976 in the Division of Animal Nutrition, ICAR–Central Sheep and Wool Research Institute, Avikanagar. Earlier research was conducted to standardize the technique of chromium di oxide as indicator for estimation of feacal output and digestibility (Krishna *et al*., 1981). Later this technique was used for estimating nutrient digestibility of sheep on pasture (Mali *et al.,* 1984) but the results obtained were erroneous due to inherent error of actual diet sampling of what animal consumed. No full proof method for estimation of dry matter intake and digestibility of sheep and goat on pasture was available till 1989. Since majority of sheep and goats are maintained on pasture and supplementation so it become imperative to standardize the method for nutrition of sheep and goats on heterogeneous grazing lands and pastures accordingly a project on Nutrient intake and utilization by range sheep in critical physiological stages under hot semiarid environment was initiated in the institute in 1993-94. First the botanical compositions of rangeland, community lands, pasture and silvipasture during different seasons were identified and nutrient contents were estimated (Sankhyan *et al.,* 1995; Shinde *et al*., 1998) in institute farms. Later on community land of Rajasthan were also evaluated under AICRP on Improvement of Feed Resources and its Utilization in Raising Animal Production (Shinde *et al*., 2004). The research on standardization of methods was initiated for actual collection of diet samples and representative samples of feaces over a period of 24 hours of sheep and goat.

Feacal begs and chromium di oxide indicator methods are widely used in grazing animals for estimation of feacal outgo. Fecal beg method is considered as time consuming, labour intensive, tedious and also difficult to keep harness in proper position in field conditions. Thus chromium di oxide indicator was found choice of method for grazing animals for estimation of fecal output (Sankhyan *et al*., 1999). This method was also compared with digestion trial in metabolic cages in sheep, it was found that indicator method underestimate the nutrient digestibility by 15% due to incomplete recovery of indigestible indicators (Sankhyan *et al*., 1997). Further dry matter intake of sheep remain non-significantly different between feacal beg and indicator method suggesting equally usefulness of indicator method for estimation of fecal output and dry matter intake in sheep on pasture (Sankhyan *et al*., 1999).

Forage samples collection of animals consumed on pasture are hand plucking (P), clipping (C), mouth grab (MG)and esophageal cannula (EC).On evaluation it was found that samples of oesophageal cannula compared to MG, P and C methods contained higher CP due to salivary contamination (Bhatta *et al.,* 1996). Also higher content of lignin due maceration of plant cell by animal in extrusasamples and release of tannin which may have elevated lignin as a result of tannin + protein reactions. Further it was observed that diet samples of animals collected in monsoon season contained relatively higher lignin than other season due to formation of artifact lignin during hot air oven drying of sample. To confirm the hypothesis, nutrient contents of esophageal extrusa samples of cannulated sheep were compared by hot air oven drying and freeze drying methods (Bhatta *et al.,* 2001). Results indicated that oven drying of samples increased lignin, NDF, ADF and cellulose contents of samples. Thus, freeze drying of samples was found choice of method. *In vitro* dry matter digestibility (IVDMD) method was also compared with lignin methods for estimation of dry matter intake and digestibility of nutrients (Shinde *et al.,* 1999) and both the methods were found equally good.

Esophageal canula for collection of diet samples in sheep and goat was not ready available in the country, later on, it was fabricated indigenously and surgically fixed in sheep first time by Karim et al. (1997). About 30% of ingested forage by sheep on pasture was collected in the sample begs and serve as sample for analysis. Esophageal canula was used in nutrition studies by Shinde et al. (1998) in round the year grazing of sheep on cenchrus pasture. Later on, this technique was stopped with implementation of guidelines from the committee for the purpose of control and supervision of experiments on animals (CPCSEA). After many years of research on development of suitable technique for collection of samples of diet of animals on pasture and determination of nutrient intake and digestibility, finally the double indicator method of lignin ratio and chromium dioxide method was standardized and used in nutrition experiments of grazing animals in the institute by several scientists.

Energy expenditure techniques and measurements

Systematic work on measurement of energy expenditure (EE) at pasture was initiated at ICAR-Central Sheep and Wool Research Institute, Avikanagar in 1996. Initially scientists at institute measured EE by gaseous exchange (O_2 and CO_2) in single tracheotomized sheep with meteorological balloon (Shinde *et al.,* 1998). The tracheal cannula was indigenously fabricated in the laboratory and surgically fixed in the sheep (Karim *et al*., 1997). Afterwards method of facemask for collection of expired air in grazing animals was also developed for short-term measurement of EE (Shinde *et al.,* 2002). Subsequently heart rate was used as measurement of EE of sheep under free range condition. Correlation of heart rate with energy expenditure in sheep was determined and it was found positive and linear (r=0.54) in different hours of grazing on pasture. Based on data, regression equation was developed for estimation of EE (EE=2.86+0.88b r=0.47; n=30) and it predicted the EE of free ranching sheep from heart rate with 77% confidence (Shinde *et al.,* 1999).

Energy expenditure of confined sheep and goats is commonly measured in calorimetric chambers. Such measurements are generally extrapolated for expressing the energy expenditure of animals at pasture (Table 3-4). This usually under or over estimates the values when compared with actual measurements made by indirect calorimetry because animals on pasture are exposed to wide range of ambient temperature, humidity and solar radiation, pasture availability and walking distance. The maintenance energy requirement of sheep at pasture is reported to be 25 to 100% greater than for animals in confinement. In semiarid region of Rajasthan, adult sheep on pasture (5.81 MJ/day) spent 40% more energy than stallfed (4.16 MJ/day) condition (Shinde *et al.,* 1996). Further sheep grazing on pasture during monsoon, winter and summer seasons spent 78, 15 and 33% more energy than stall-feeding mainly due to seasonal changes in ambient temperature, energy cost of locomotion and thermoregulation (Shinde *et al.,* 1998).

Table 3. Effect of season and activities on energy expenditure of sheep on pasture

Season	EE ($kJkg^{-1}d^{-1}$)	Activities	(MJ/day)
Monsoon	223.26	Stall-feeding	4.16
Winter	136.76	Grazing	5.81
Summer	161.08	Per cent increase at grazing	39.66

Source: Shinde *et al.* (1996)

Table 4. Effect of season and activities on energy expenditure of goats (Joule/sec) on pasture

Season	At stall (6.00h)	At grazing (14.00h)	Increase at grazing
Monsoon	107.8	389.0	2.63 times
Winter	32.7	140.2	3.28 times
Summer	52.0	391.3	6.52 times

Source: Shinde *et al.* (2002)

Protein and energy intake of sheep and goat on pastures

Native ranges of semi-arid region are good source of quality vegetation to animals after rains in the monsoon season. Thereafter, the forage availability and quality gradually declined with the progress of season from monsoon to summer. In summer when ranges are poorly occupied by vegetation cover, the dry matter intake of sheep declined by 25 per cent from monsoon. This resulted in loss of growth and body weights of animals. Sown pasture of *Cenchrus ciliaris*in comparison to native ranges ensure maintenance requirement of adult sheep even during summer season. Goats in comparison to sheep has advantages as they have flexible and opportunistic browsing behaviour, which helps them to adapt to various range conditions and maintain dry matter intake between 2.0-2.1% of body weight.

Digestible crude protein (DCP) intake of sheep on ranges declined up to 70-75% in summer (3.44 $g/kgW^{0.75}$) compared to monsoon (1.05$g/kgW^{0.75}$) because of decline in forage intake and nutrient digestibility with maturity. On the contrary, goats on native ranges maintained an intake of 4.8 in monsoon to 4.5$g/kgW^{0.75}$ in summer, which is sufficient for maintenance and outdoor activities. It has been reported that native browse species rich in protein meet the protein requirement of goats in ranges (Shinde *et al.,* 2000).

Energy intake of 6-9 MJ/h/d in sheep and goats on pasture of semiarid region has been reported, which is found insufficient for normal maintenance and outdoor activity. Moreover, in dry period when forage matures and gets lignified, the energy intake further reduces because of poor digestibility. ME intake of goats did not fluctuate during different seasons because they primarily thrived on browse species rich in nutrients. In summarizing the several studies on protein and energy intakes of sheep and goats on pastures, it clearly showed that animals meet their CP requirements during all the seasons by selective grazing/browsing while remain deficient in energy intake during the entire year.

Lambs and kids on *H. binata* based silvipasture during growing (August-October) and post growing (November-January) seasons and concentrate supplementation (1% of body weight) showed higher DCP intake (5.39 vs 5.34g/kgW$^{0.75}$) in September in both the species as compared to December (3.66 vs 3.94g/kgW$^{0.75}$) while comparable ME intake (MJ/kgW $^{0.75}$) between the species and seasons (Das *et al*., 2019).The crude protein content of pasture was reduced from 8.37% to 6.81% with maturity of pastures. CP digestibility of forage decreased from growing to post-growing season, both the species showed significant difference in daily gain for growing and non-growing seasons. Dry matter, digestible crude protein and metabolizable energy intake of sheep and goats on rangelands and Cenchrus pasture from several studies conducted at the institute are summarized below (Table 5).

Table 5. Dry matter, crude protein and energy intakes of sheep and goats on rangelands and pastures

Grazing lands	Season	DMI (g/kg W$^{0.75}$)	DCP (g/kg W$^{0.75}$)	ME (MJ/kg W$^{0.75}$)
Sheep				
Rangelands	Monsoon	49.6	3.44	0.39
	Winter	43.7	2.42	0.34
	Summer	29.2	1.05	0.22
Cenchrus pasture	Monsoon	36.9	2.10	0.29
	Winter	64.0	4.70	0.48
	Summer	53.0	2.50	0.29
Goats				
Rangelands	Monsoon	82.0	4.80	0.90
	Winter	62.4	3.10	0.78
	Summer	81.6	4.50	0.80
Cenchrus pasture	Monsoon	64.0	4.10	0.65
	Winter	54.0	2.80	0.69
	Summer	55.9	3.00	0.75

Source: Shinde *et al*. (1998), Shinde *et al.* (2000)

Grazing and browsing behavior of sheep and goat on pasture

It is essential to study seasonal composition of the diet and grazing behaviour throughout the year to gain an understanding of the foraging strategy adopted by the sheep and goats to ameliorate the effect of feed scarcity to sustain the production in harsh conditions of desert environment. Basically, sheep is a grazier and goat is browser animals, but they alter their behavior in relation to availability of vegetation. Goats have a characteristic bipedal stance, which give them an advantage in consu-mption of several tree species and overhead portions of shrub species, goat diet contains 76% shrubs and 24% grasses in monsoon and almost 100% in winter and summer. Preference for grasses was found by goats was found in monsoon only, not in other seasons while sheep preferred grasses in all the seasons from100 % grasses in monsoon and winter to97% grasses and 3% shrubs in summer seasons.

Selection of protein rich vegetation by sheep and goats progressively increased with the deterioration of pasture conditions (Table 6). The preference index (PI) of crude protein was 1.2 in monsoon which increased to 2.1 and 3.0 in winter and summer, respectively, while PI of ADF and cellulose declined from 0.99 and 0.98 in monsoon to 0.76 and 0.73 in summer respectively in sheep (Shinde *et al*., 1998). PI of CP progressively increased from 1.3 in monsoon to 1.9 and 2.2 in winter and summer, however, PI of lignin and ADF increased from monsoon to winter and summer in goats because of greater preference of goats to mature browse species with progress of season during wet to dry period (Bhatta *et al*., 2001).

Sheep and goats adjust their grazing behaviour to ameliorate the effect of harsh environment. They follow rhythmicperiodicity in grazing pattern on pasture during all the seasons. During summer, sheep and goat spend fewer hours on grazing with rise of ambient temperature. They prefer shade during peak hours of the day to ameliorate the effect of hot sun. Grazing period of goats was found negatively correlated with ambient temperatures, relative humidity and forage supply from ranges. Goat spent maximum hours under shade during peak hours of the day during monsoon and summer, when ambient temperature rises to 42 to 45°C.They also make several adjustments in food processing behaviour for efficient intake and utilization of feed. Sheep increases ruminating rate (chew/bolus) and decrease masticating rate (chew/min) with rise of fibre contents of the diets (Shinde *et al.,* 1998). Similarly goats have the ability to utilize fibrous diet and ruminating rate increases from 45 chew/min in monsoon, when the diet contains 68% shrub and 32% grasses to 70 chew/min in summer, when diet consists of almost shrubs (Bhatta *et al*., 2001).

Soil ingestion and its effect on animal's health

Sheep usually grazed close to ground because of their close grazing habit. This habit causes soil ingestion in animals and vary between seasons because of vegetation contaminations and ground covers. Soil ingestion damaged the gut mucosa and increased the

Table 6. Nutrient selectivity of sheep and goats on pastures

Parameter	Sheep			Goat		
	Monsoon	Winter	Summer	Monsoon	Winter	Summer
Crude protein	1.19	2.12	3.00	1.35	1.78	2.25
Neutral detergent fibre	0.99	0.77	0.85	0.93	0.86	0.65
Acid detergent fibre	0.99	0.95	0.76	0.89	0.86	0.56
Cellulose	0.98	0.84	0.73	0.64	0.79	1.03
Hemicellulose	0.97	0.50	1.61	1.05	0.86	1.24
Acid detergent lignin	1.90	2.20	0.81	2.00	1.68	0.66

Source: Shinde *et al*. (1998); Bhatt *et al.* (2001)

excretion of endogenous nitrogen, rapid wearing of incisor teeth and bruising of dental pad. In drought years, soil ingestion increased because of poor vegetation cover of grazing lands and adversely affected the nutrition and health of animals. Vaithiyanathan and Singh (1994) reported soil ingestion of 71 to 163g during different seasons in sheep grazing on sewan (*Lasiurus sindicus*) pasture of arid region. A study conducted in a drought year on community lands of semiarid regions indicated that sheep ingested 269, 111 and 309 g of soil daily while grazing which constituted 39.10, 15.62 and 46.41 % of dry matter intake during monsoon, winter and summer, respectively(Shinde *et al.,* 2005). It adversely affected the digestion of nutrients resulting in loss of body weights and production and mortality.

Mineral deficiency in grazing sheep and goats

Minerals are an important component of animal nutrition. In free grazing sheep and goats of dry regions, minerals derived from natural feedstuffs are often inadequate and require supplementation to satisfy animal requirements. The amounts of nutrients, including minerals, in the forages greatly varied depending on soil, plant species, and management factors etc (Shinde and Sankhyan, 2008; Shinde *et al*., 2009). Mineral deficiencies adversely effect on both animal production and health. A study conducted under AICRP on Improvement of Feed Resources and Nutrient Utilization in Raising Animal Production indicated wide spread deficiency of Ca, P, Zn and Cu in sheep and goats of semiarid regions of Rajasthan (Shinde and Sankhyan, 2007). To mitigate the deficiency, an area specific mineral mixture pellets were prepared by incorporating the required concentration of 22.86% calcium, 17.66% phosphorus, 0.39% zinc, 0.31% copper and 0.07% cobalt. Field testing of pellets supplementation showed improvement in male and female reproduction, lamb growth, early puberty, wool and milk yield and reduced skin keratinization, wool shedding and urinary calculi, improved resistance against diseases and feed utilization efficiency in sheep and goats (Shinde and Sankhyan, 2010). At present inorganic salts of mineral mixture are invariably supplemented to animals. They are poorly absorbed and retained in the system, on the other hand, chelation of these minerals with amino acids and peptides enhance its bioavailability. A study was undertaken to evaluate the effect of supplementation with Cu- and Zn-methionine in lambs indicated that it increased Cu and Zn absorption and retention and its concentration in wool and improved wool characters and quality crimp, tensile strength and elastic properties beneficial for quality yarn (Shinde *et al.,* 2013).

Grazing system of animals

Continuous system of grazing is very common in the country where sheep and goats are grazed on the same pasture throughout the year without any rest to pasture. In rotational grazing system, pasture lands is divided in plots and animals are grazed at an interval of 15 days in each plot. In deferred rotational grazing, one paddock is protected from grazing and forage is cut from paddock and conserved as hay for feeding to animals during scarcity. In cut and carry system, forage from paddocks are cut and fed to animals at stall. A study was conducted under Inter-Institutional Collaborative Project on Effect of grazing different types of grasslands on sheep and goat productivity (1990-93). A plot of 16 ha was divided into 4 sub plots of 4ha each. Four animals/ha (2 sheep and 2 goats) along with followers were grazed under continuous, rotational, deferred rotational and cut and carry system for a period of 3 years (Shinde *et al.,* 1993). In continuous grazing system, forage yield and quality were deteriorated and palatable species were removed from grazing lands and after 3 years of continuous grazing, grazing lands were found remain with unpalatable and woody species. Rotational grazing of sheep and goats on pasture improved the pasture yield and quality. Also upstream erosion and downstream flooding was decreased in the rotational grazing plots. Loss of water by runoff and evaporation was also reduced. Deferred rotational system, improved the grass growth and produced more forage and also ensured seed production besides forage.

At IGFRI, Jhansi also, three grazing management (continuous, rotational and deferred rotational) were studied on a natural vegetation to evaluate its effect on soil, pastures and animals (Pailan *et al.,* 2007). In each grazing system, four plots of 1 ha each was taken and grazing was allowed @ 1.5 ACU/ ha in mixed herd of sheep, goats and heifers throughout the year. From July to October, the animals were maintained only on grazing and thereafter from November to June, they were supplemented with concentrates to meet nutrient requirements. It was observed that rotational or deferred rotational had comparatively better performances (Table 7) over continuous grazing system in terms of less soil and nutrient loss, improved soil fertility, higher biomass yield and animal production.

Animal performances, growth and reproduction

Sheep and goat production on grazing lands are considered as organic in nature because they are maintained on natural vegetation free from pesticides, insecticides and other chemicals. A study was conducted for screening of pesticide residues in sheep meat and milk in the Jaipur market and nearby villages of institute, suggested no pesticide residues in it and safe for human consumption (Shinde and Karim, 2009).Several studies on production performance of sheep and goats on rangelands of Rajasthan indicated that farmers sold their male lambs and kids at 3-4 months of age weighing 12-14 kg in the market for meat purposes. Scarcity of feed from grazing is one of reasons which compel them to sale their lambs at an early age. In grazing system on rangelands, sheep are shorn three times in a year in June, September and March and produced 1.0 to 1.2 kg of wool annually. Animals also produced small amount of milk after weaning of lambs and mostly used by farmers in their households. The goats in rangeland of Rajasthan, yield relatively higher than sheep and milk is also used by farmers in their households. It has been observed that overall productivity of sheep and goats on rangelands is low due to poor forage supply and quality, and productivity can be improved with supplementation of feeds and forages (Table 8).

The supplementation of limited amount of concentrate (1.5-2.0% of BW) in addition to grazing on cenchrus pasture increased the finishing weight of 25-28 kg at six months of age (Shinde *et al.,* 1995). Chaturvedi et al. (2010) also recommended supplementation of concentrate feed @ 1.5% of body weight to lambs on community land in semi-arid region for higher growth rates (95.9 g daily). In other studies also supplementation of concentrate feed at the rate 350 g daily during last 45 days of pregnancy in sheep (Sankhyan *et al.,* 2007), 300 g daily to pregnant and lactating ewes (Chaturvedi *et al.,* 2003), 400 gas flushing ration prior to mating season to ewes (Chaturvedi *et al.,* 2012) on community lands has been recommended for improving fertility, body condition and birth weights of lambs.

Table 7. Soil nutrient loss, fertility status and herbage biomass production under different grazing management systems

Attributes	Grazing systems		
	Continuous	Rotational	Deferred rotational
Soil and nutrient loss			
Soil loss (tons/ha)	5.66	3.13	4.12
Soluble salt (kg/ha)	17.37	12.85	12.92
Available-N (kg/ha)	2.73	2.49	2.42
Soil fertility			
Organic carbon (%)	0.51	0.55	0.57
Available-N (kg/ha)	192.6	209.2	215.2
Available-P (kg/ha)	6.69	6.98	7.45
Available-K (kg/ha)	160.0	170.3	182.4
Herbage yield and quality			
Dry herbage biomass yield (t/ha)	7.41	7.86	8.03
DM (%)	46.23	44.05	44.44
CP (%)	5.52	5.65	5.86
NDF (%)	73.02	71.95	70.93
ADF (%)	50.60	47.08	47.27

Source: Mahanta *et al*. (2013)

The study conducted in the institute showed that grass pastures of Cen*chrus ciliaris* ensured quality forage to animals, Mutton synthetic lambs attained 13.9 kg at 3 months and 20.6 kg at 6 months of age (Singh *et al.,* 2003) and 18.00 kg at 3 months of age in Avivastra lambs (Shinde *et al.,* 1996). Silvipasture has added advantages of quality forage supply to animals from grasses, browse and tree species. Lambs and kids attained 22 kg body weights at 6 months of age on silvipasture (Sankhyan *et al.,* 1996) and 30 kg body weight at yearling age in lambs (Shinde *et al.*, 1994). Acacia pods from tree component in silvipasture improved multiple births (25%) as compared to 2-3% under conventional system in Kutchi goats (Bhatt *et al.,* 2002). Ardu fodder tree (*Ailanthus excelsa*) in silvipasture supplied green leaves and their supplementation in sheep increased the milk yield by 63% (Shinde *et al.*, 1996). In dry regions of Rajasthan, *Prosopis cineraria* (tree) and *Zizyphus nummularia* (shrub) leaves under routine practices are harvested during winter season and conserved for feeding to animals during scarcity period. Bhatta *et al.* (2005) suggested maximum nutritional benefits of these tree/shrub leaves can be harvested if used as a supplement (25-30% of total feed intake) rather than as a sole feed.

Table 8. Performances of sheep and goats under grazing with supplementation of feeds/forages

Pasture	Parameters	Sheep	Goats	References
Community grazing land	Lambs grazing on community lands	Attained 20.22 kg b. wt. and 46.75g av. daily	-	Jalajakshi *et al.* (2016)
Community grazing land	Supplementation of lambs with 1% b.wt. for 120 days	Attained 26.39 kg b. wt. and av. daily gain 96.65g	-	Jalajakshi *et al.* (2016)
Community grazing land	Supplementation of conc. mix @1.5% b.wt. to 3 month old male lambs for 90 days	Av. body wt. gain 90 days (8.63 kg) and av. daily gain 95.9 g	-	Chaturvedi *et al.* (2010)
Community grazing land	Supplementation of 400 g conc. mix during entire late gestation to early lactation	Improved body wt. at lambing, birth wt. of lambs 4.02 kg and milk yield of ewes increased up to 250 g per day	-	Chaturvedi *et al.* (2011)
Community grazing land	Flushing of ewes with 400g conc. mix.	Improved conception rate, lambing rate, body wt. of ewes and birth wt. of lambs	-	Chaturvedi *et al.* (2012)
Cenchrus ciliaris pasture	Weaning weight (3 months) of lambs (kg)	18.17±1.10	15.42±0.86	Shinde *et al.* (1996)
	Average daily gain (g)	163±12.52	135±8.84	
	Greasy fleece yield (kg)	Autumn 0.970±0.80 Spring 1.430 ±0.91	-	
	Daily milk yield (g)	714±50.09	-	
Silvipasture (*C. ciliaris* + *Dicrostachys nutan* + *Ailanthus excelsa*)	Six month wt. (kg)	19.93±1.23	21.90±0.63	Sankhyan *et al.* (1996)
	Yearling wt. (kg)	30.07 ±1.48	-	Shinde *et al.* (1994)
	Daily milk yield (g)	467±73.31	-	Shinde *et al.* (1996)
Cenchrus pasture	Daily milk yield (g)	310 ±56.29	-	Shinde *et al.* (1996)
Silvipastoral system	Av. daily gain (g)	69.2	75.4	Rai and Rai (2010)
L. leucocephala based silvipasture	Av. daily gain (g)	87.2	-	Rao *et al.* (2013)
L. leucocephala based silvipasture	Lambs wt.gain (kg) per ha	236	-	Rao *et al.* (2013)
H. binata based silvipasture	Av. daily gain (g)	53.9±1.48	48.9±1.58	Das *et al.* (2019)

The study conducted in other locations in dry region of country also showed beneficial effects of silvipasture (Das *et al*., 2019). Silvipasture grazing improved 33% and 39% higher growth in lambs and kids and increased milk yield by 63.8%, respectively over natural grassland (Rai and Rai, 2010). Similarly Rao *et al.* (2013) reported 4.11 t/ha more forage than the natural pasture (1.36 t/ha) and average daily gain of 87.2 g in the silvipasture (*L. leucocephala*) and 59.1 g in the natural pasture in ram lambs. Cut and carry system of *Stylosanthes scabra* in coconut based hortipasture model in goat rearing also recommended by the Gunasekaran *et al.* (2013).The supplementary feeding of concentrate feed to Marwari kids from 3-6 month of age in silvipasture to improved body weights at slaughter (22.4kg body weight at 6 month of age) also suggested by Sankhyan *et al*. (2002).

Rejuvenation of grazing lands

Rejuvenation of grazing lands for improvement in forage supply are based on approaches like protection of grasslands for vegetation recovery, removal of unwanted bushes, re-seeding of grasslands with perennial and productive species of grasses and legumes (Table 9), application of fertilizers for higher productivity and subsequently utilization of grassland either through cutting or grazing in a suitable manner. Overgrazing leads to degradation of grasslands resulting in dominance of unpalatable and noxious vegetation. Protection from grazing through fencing leads to significant recovery of vegetation status. Studies conducted at ICAR-IGFRI, Jhansi indicated an increase in herbage yield from 0.1 to 3.5 tonnes/ha within 3 years of protection of degraded grazing lands with increase of plant population of desired perennial grasses. Infestation of bushes in grazing lands also negatively affects the availability of open space for growing grasses and thereby reduces forage yield. The standard practice of bush cleaning includes either manual or mechanical felling or removal of stumps, or application of selective weedicides/herbicides on the cut stumps to kill them and stop coppicing. Application of fertilizer had also positive impact on forage availability from grasslands. But the response was highest in nitrogen followed by phosphorus. Studies conducted at ICAR-IGFRI, Jhansi indicated that application of 40-60 kg N/ha and 20-30 kg P_2O_5/ha increased forage production by 50-100% in majority of grasses besides improvement in quality, particularly in protein content. During the course of animal grazing, certain grasses are preferred while others are left. Because of this selective grazing, the populations of desirable species tend to get reduced in grasslands much faster than undesirable species. Most of the perennial grasses utilize the reserve food material that remain stored in the underground parts and produce new shoots. When this reserve food material is exhausted faster through over grazing and perennial grasses are then unable to re-generate due to non-availability food reserve. Hence, certain period of rest is essential for the perennial grasses to recoup and rejuvenate.

Table 9. Grass and legume species suitable for re-seeding/introduction in degraded grazing lands of dry areas

Rainfall (mm)	Grass/ Legume	Soil type	Dry forage yield (t/ha)
< 350	Buffel grass (*Cenchrus ciliaris*)	Sandy to sandy loam	4.0
	Bird wood grass (*Cenchrus setigerus*)	Sandy to sandy loam	3.0
	Sain (*Sehima nervosum*)	Red, gravelly to sandy loam	2.5
	Stylo *(Stylosanthes scabra)*	Sandy to sandy loam	2.5
	Butterfly pea *(Clitoria ternatea)*	Sandy loam to silty clay loam	3.0
	Bankulthi *(Atylosia scarabaeoides)*	Gravelly, sandy loam well drained	2.0
350 - 500	Blue panic (*Panicum antidolate*)	Loam to sandy loam	3.0
	Marvel (*Dichanthium annulatum*)	Loamy to clay loam	2.5
	Dinanath grass (*Pennisetum pedicellatum*)	Loamy to clayey loam	3.0
	Bahia grass (*Phapalum notatum*)	light	3.5
	Sabi grass (*Urochloa mosmabicensis*)	Sandy to sandy loam	3.0
	Stylo *(Stylosanthes hamata)*	Sandy loam to loam	3.5
500-700	Rhodes grass *(Chloris gayana)*	Sodic, loam to sandy loam	2.5
	Stylo *(Stylosanthes hamata)*	Sandy loam to loam	3.5
	Siratro (*Macroptilium atropurpureum*)	Sandy to sandy loam	1.8
> 700	Napier grass (*Pennisetum purpureum*)	Sandy loam to clay loam	4.0
	Marvel (*Dichanthium annulatum*)	Loamy to clay loam	2.5

Source: Kumar and Kumar (2001)

Table 10. Potential silvipasture models for degraded grazing lands in dry areas

Tree	Pasture component	
	Grass	Legume
Acacia nilotica	*Cenchrus ciliaris*	*Stylosanthes hamata, S. scabra*
	Dichanthium annulatum	*Stylosanthes hamata*
Acacia tortilis	*Cenchrus ciliaris, Cenchrus setigerus*	*Stylosanthes hamata, S. scabra*
	Dichanthium annulatum	*Stylosanthes hamata*
Azadirachta indica	*Cenchrus ciliaris*	*Stylosanthes hamata*
	Dichanthium annulatum	*Stylosanthes hamata*
Albizia amara	*Cenchrus ciliaris, Cenchrus setigerus*	*Macroptilium atropurpurreum, Stylosanthes hamata*
	Dichanthium annulatum	*Stylosanthes hamata*
Albizia lebbeck	*Panicum maximum*	*Stylosanthes hamata*
	Cenchrus ciliaris, Cenchrus setigerus	*Clitoria ternatea, Stylosanthes hamata*
	Chrysopogon fulvus	*Clitoria ternatea, Stylosanthes hamata*
Albizia procera	*Sehima nervosum*	*Clitoria ternatea, Stylosanthes hamata*
Dalbergia sissoo	*Cenchrus ciliaris, Cenchrus setigerus*	*Clitoria ternatea, Stylosanthes hamata*
	Cenchrus ciliaris	*Stylosanthes hamata, Stylosanthes scabra*
Emblica officinalis	*Dichanthium annulatum*	*Stylosanthes hamata, Stylosanthes scabra*
	Cenchrus ciliaris	*Stylosanthes hamata*
Hardwickia binata	*Dichanthium annulatum*	*Stylosanthes hamata*
	Cenchrus ciliaris + Chrysopogon fulvus	*Macroptilium atropurpureum, Stylosanthes hamata*
	Sehima nervosum	*Clitoria ternatea, Stylosanthes hamata*
Leucaena leucocephala	*Panicum maximum*	*Stylosanthes hamata*
	Cenchrus ciliaris, Cenchrus setigerus	*Stylosanthes hamata, Stylosanthes scabra*
	Dichanthium annulatum	*Stylosanthes hamata, Stylosanthes scabra*
Zizyphus mauritiana	*Panicum maximum*	*Stylosanthes hamata*
	Cenchrus ciliaris	*Stylosanthes hamata*

Source: Roy *et al.* (2005)

Different silvipastoral systems have been indicated as low input technology for rejuvenation/rehabilitation of grazing lands and to meet the deficit of forage resources for animals besides supply of fuel woods and timbers (Table 10). Long term studies conducted on certain pastures indicated that if properly established and managed these pastures could be reasonably productive even up to 8 to 9 years, except the establishment year, when pasture production is normally low and varied from 1.8 to 2.5 t DM/ha.

Again it is true that small ruminants are the major source of livelihood for the poor, but they are also detrimental to natural resources when grazed at high grazing pressure on the land. An investigation was carried for the density classes of small ruminants for 167 prioritized and rain fed districts of India in relation to natural resource index (NRI) classes by National Rain fed Area Authority, New Delhi. It was observed that out of 167 districts, 44, 62 and 61 districts came under the category of low, medium and high density of small ruminants, respectively.

Therefore, the interventions to promote small ruminant production should be in conformity with resource base to avoid land degradation. Areas of high density with low natural resource index are prone to further degradation. Therefore, efforts should be made to reduce the density and promote alternate enterprises (Table 11**)**. It is expected that following strategies/interventions will help to improve the nutrition and productivity of small ruminants.

Conclusion

Conservation and propagation of existing grasses pastures and fodder tree require priority for small ruminants. Further the vast lands available under different heads need to be rehabilitated with grass pasture to ensure round the year supply of quality forage to animals. Further grazing of animals as per carrying capacity and rotational grazing may be followed for best utilization of resources. The available grazing land systems for small ruminants are not sustainable mainly due to inadequate supply of feed and fodder round the year. A supplementary feeding of conserved fodder, green fodder, tree leaves

Table 11. Interventions based on small ruminants' density and natural resources index (NRI)

NRI	Small ruminants density (No./km²)		
	Low (< 35)	Medium (35-71)	High (>71)
Low	Maintaining the number animals,Productivity enhancement of pasture lands through soil and water conservation measures and top-feed trees	Silvopastoral systems and supplemental feeding by growing fodder trees	Reducing the number and increasing the productivity by convincing the small ruminants rearing communities. Breed improvement
Medium	Opportunity exists for agroforestry systems by integrating small ruminants which are more remunerative	Situation is in equilibrium but needs improved animal ealth and supplemental feeding	Development of community owned lands and CPRsthrough user groups (UGs) and promotion of perennial grasses and legumes
High	Scope for promotion of agrosilvo- pastoral, silvopastoraland hortipastoral systems byintegrating small ruminants	More focus on animal health care and integrated farming systems approach	Improvement in grazing lands through agroforestry and soil and water conservation measures. Introduction of deferred and rotation grazing through community mobilization

Source: NRAA (2012)

and concentrate mixture should be followed after grazing in these animals during critical months of feed scarcity during summer and also during critical stage of growth, pregnancy and lactation in animals.

Indeed, the nutritional support from pastures and grazing lands for small ruminants should be based on the sound ecological principles and on the sustainable basis, accordingly the general guidelines may be followed-

- Grazing of animals should be allowed at appropriate stage of herbage maturity.
- Combination of legume and grasses in pasture is always good, but they should be compatible to each other.
- Excess forages/pasture grasses should be conserved as hay or silage for use during the lean period.
- Every pasture land depending on the soil fertility and agro-climatic conditions has a carrying capacity and animal grazing need to be based on carrying capacity of land.
- Too frequent grazing is detrimental at the same time only occasional grazing is also not good and therefore, there is a need of appropriate grazing strategies.
- Appropriate soil and water conservation measures need to be adopted to maximize the production from pastures and grazing lands.
- Trees/shrubs should also be grown in the pastures, which will provide foliage during summer in a complementary way with grasses.
- Pastures and grazing lands should be managed in such a way that it forms an ecologically feasible unit.

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